SECTION III

ARCHITECTURAL IMPACT

OF PROTECTIVE GLAZING

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Aesthetic Impact of Protective Glazing

During the field survey, church and temple administrators and clergy were asked how they liked the way protective glazing <u>looked</u> on their building today...73% said they did not like the way it looked. None of those who had purchased plastic PG materials were happy with their appearance today. Although the glazing industry has claimed many advantages for PG, no one claims that it will actually make the stained glass look better. Windows that are not covered with PG look the best **[Fig 19., 20. 21. & 22.]**.

The design, materials, and installation of secondary glazing can have a serious aesthetic impact on the stained glass windows as well as a building's architectural design. The exterior appearance of many stained glass windows is nearly as important as their interior appearance. This is particularly true of ecclesiastical architecture. Virtually all Gothic revival churches rely on pointed-arched window frames and delicate window tracery to accentuate the vertical emphasis of the design **[Fig 23.]**. When a conventional grid is installed over the original frame, this crucial design feature is lost and the building's architectural character is severely compromised **[Fig 24.]**. American churches, temples and mosques designed in Byzantine, Romanesque and Renaissance revival styles often feature deeply recessed window openings to punctuate their heavy architectural massing. When PG is installed several inches forward or flush with the outer molding, or large when sheets of PG create surface reflections, the window no longer reads as an aperture and the architectural effect is lost **[Fig 25. & 26]**. With the exception of leaded PG which follows the original stained glass design, all protective glazing systems obscure the leading pattern and texture of the stained glass windows, which are important to the perception of the building from the exterior.

Color & Light: Although the color of stained glass is mostly viewed through transmitted light (from inside), some stained glass -- particularly opalescent glass -- is nearly as beautiful when viewed from the exterior **[see Figs 21. & 22.]**. Most glass products today are very stable and will retain excellent clarity over the years. However, it is important to consider how light will play off the glass surface. Reflections and glare can be very disconcerting when PG is viewed from an angle **[Fig 27.]**. Some historic and contemporary PG systems have used leading, either figurative or geometric, to break up the broad expanse of glass or sheeting and mitigate the glare. On primary facades, and where leading and texture are of great importance to the perception of the building, this can be a worthwhile approach. Leaded PG is expensive however, typically costing over $100 per square foot.

Plastics are also susceptible to glare but their primary downfall is that when exposed to sunlight and weather, over time all plastics will cloud and yellow. Cloudy PG appears almost opaque, more like a painted surface than a window. Out of 60 plastic PG installations surveyed, only those installed in the past few years still had reasonable clarity. Manufacturers recognize this chronic problem and do not warranty their products beyond a few years. Plastics are also difficult to clean since they scratch easily. **In terms of aesthetics, all plastic products are a poor investment.** The appearance of a plastic installation is certain to decline in a relatively short period of time.

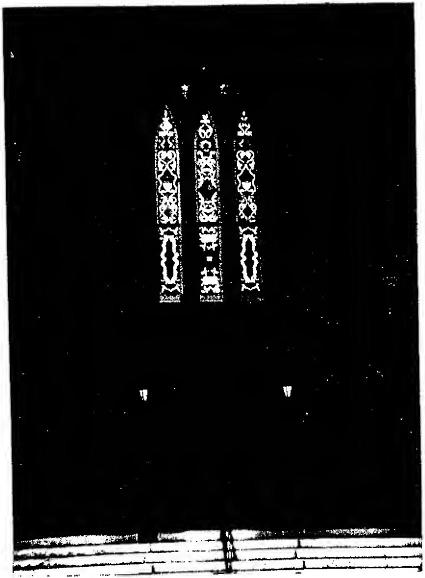

Fig 19. The stone and glass harmonize without PG.

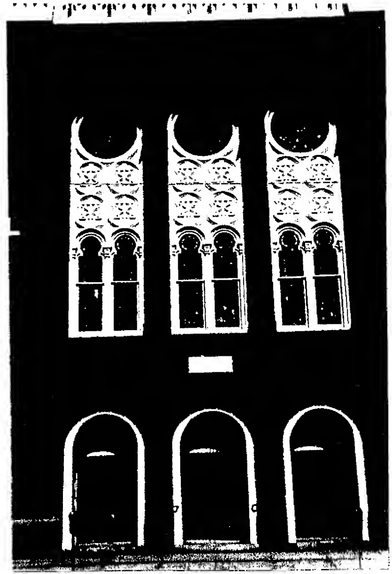

Fig 20. Crisp details and texture can be seen without PG.

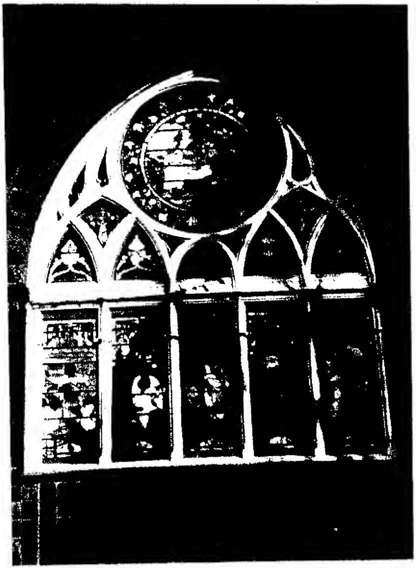
Fig 21. Opalescent glass adds color to the exterior.

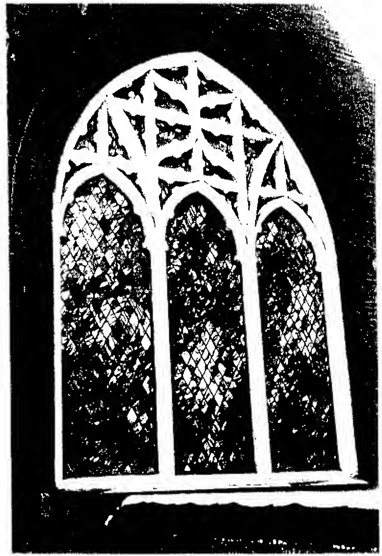
Fig 22. Even simple art glass looks better without PG.

Fig 23. PG over the tracery would alter these windows.

Fig 24. The delicate tracery of this window is completely hidden.

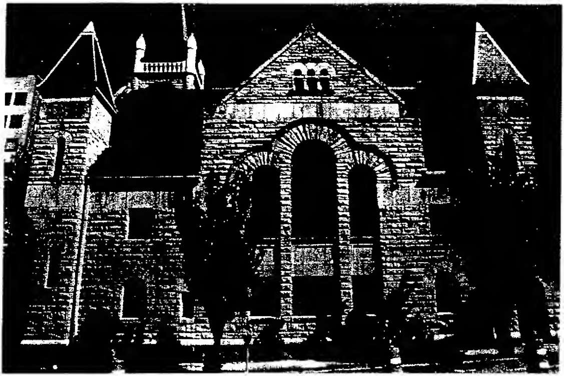

Fig 25. Romanesque Revival churches rely on the shadow effect of deep, recessed windows.

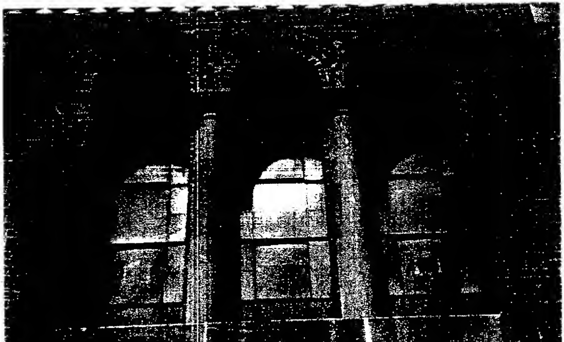

Fig. 26. Due to cloudy PG, these windows no longer read as apertures in the wall.

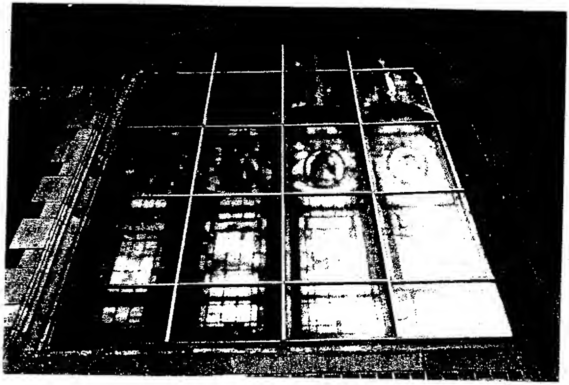

Fig 27. The art glass in this installation is blurred by glare and textured PG.

Window Framing: The design of the PG framework should be compatible with the design, materials and color of the original stained glass window frame. Installations in which the glazing is cut to fit within the existing mullions or conform to the tracery are visually most successful **[Figs 28. & 29.]**. Linear frames or grids are faster, easier and cheaper to install than curvilinear frames and have become a popular method of installing PG. Of the 100 installations randomly surveyed, 64% had PG frames which did not conform to the original window frame; most of the remaining 36% had simple shapes without any interior framing. Moreover, the color of the PG frame clashed with that of the stained glass window frame in 42% of these installations. An advantage of wood and steel PG frames is that they can be painted to match or compliment the original frame and surrounding trim. Aluminum frames do not hold paint well but are available in anodized colors, typically ranging from silver to bronze to black (see **Appendix B**). Materials should be selected carefully to enhance rather than detract from the windows and architecture; aluminum or silver metallic colors should generally be avoided.

A subtle but important factor in the design of secondary glazing systems is the extent to which the installations reduce the apparent depth of the window opening. Because PG frames are often set against outer moldings, or the PG is merely screwed directly into the frame, it may be nearly flush with exterior wall surfaces **[Fig 30.]**. The window is no longer perceived as an aperture or an opening, and the building appearance may be dramatically altered. It is therefore important to install PG within the window opening, maintaining at least a 1" interspace between the PG and the stained glass.

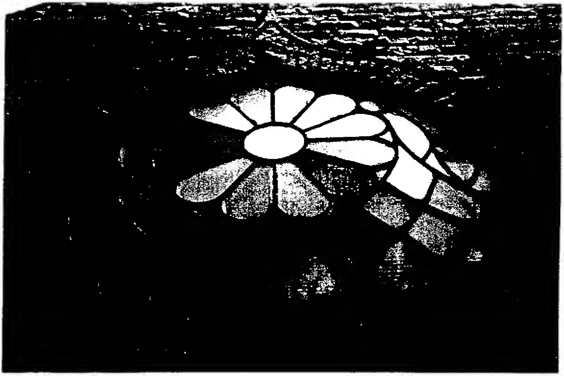

Fig 28. This PG needs maintenance, but the muntins conform to the tracery.

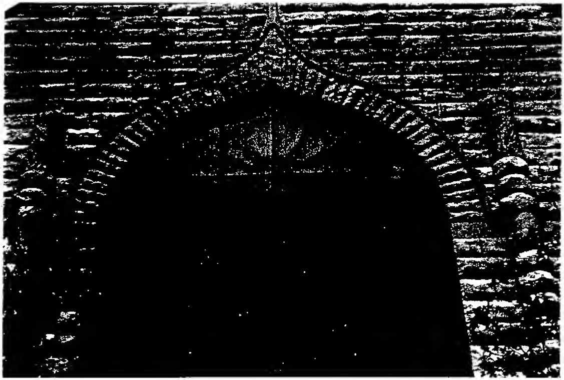

Fig 29. Another PG installation on the same building disregards the tracery.

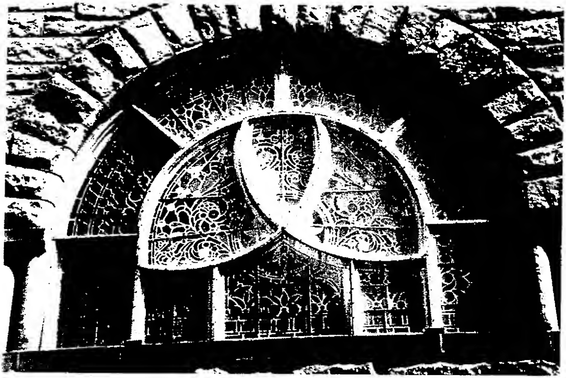

Fig 30. Only a few years old, this PG will haze and obscure the window reveal.

Maintenance and Protective Glazing

Protective glazing is often promoted to alleviate window maintenance. Unfortunately, the field survey revealed that PG is typically installed in a fixed position as a barrier to window maintenance. Paints and sealants (and the materials they protect) continue to deteriorate from ultra-violet light and moisture that inevitably gains access before exterior sealants are renewed. Moreover, it is readily apparent that PG gives building owners a false sense of security; and that annual window maintenance is often overlooked as a property management responsibility. Even if failing paint and deteriorating wood become apparent, congregations are reluctant to remove a system that was installed at significant cost, because removal and remounting may be difficult and time consuming. Frame problems concealed behind cloudy secondary glazing are "out of sight and out of mind" and maintenance is neglected.

Leaks behind PG can cause serious deterioration of the window frame supporting the leaded glass. New PG installations often remain watertight for several years before deterioration begins. Typically the contractor warranty has expired and the owner must pay to have the PG removed temporarily or permanently in order to maintain the very window it was installed to protect! In addition to raising moisture levels, accelerating deterioration, and preventing maintenance, secondary glazing prevents normal window operation. Almost all churches require some ventilation during various seasons, and permanently mounted secondary glazing often immobilizes original stained glass ventilators. It is common to see secondary glazing systems where panels have been removed to expose ventilators, allowing them to operate.

Polymer sheets, such as acrylic and polycarbonate, have a much greater coefficient of thermal expansion than glass, and sheets may bow and break sealant joints if the secondary glazing is improperly installed (see **Fig 6.**). Even when PG is properly mounted in a removable sash, leakage behind the sash is likely to be a recurring problem. Small cracks in the sealants allow a surprising amount of water to collect behind the glazing in areas subject to runoff or wind-driven rain. Unvented PG does not allow water to drain or evaporate, and trapped moisture leads to condensation and high humidity in the interspace. Protective glazing, whether vented or not, alters the drip details at the window sill, sometimes creating a dam for ponding water unless weep holes are added to drain water away.

<u>If</u> sealant integrity could be maintained, condensation would not occur. Unfortunately, due to the nature of leaded glass, and the high expansion/contraction of lead came, it is impossible to hermetically seal stained glass with secondary glazing alone. This can only occur with a triple-glazed unit, when the stained glass sandwiched in the middle (see **Section V**).

Wooden tracery of Gothic windows is most at risk. Laminations and joinery in woodwork readily admit water once the paint and sealants fail. Unvented windows, where humidity and temperatures are high may exhibit rot or delamination in only a few years. Metal and masonry surrounds are not immune to damage. Iron frames or mountings often rust more quickly in high humidity conditions beneath "protective" glazing systems than if exposed to the weather. Pack rusting of window supports may deform glass and crack masonry. Severe rusting and loss of metal in iron mountings can necessitate frame replacement. While stone tracery is generally more tolerant of improperly installed PG, damage often occurs through the use of impermeable sealants and inappropriate anchors. When sealants are placed directly on the stone surface, they may trap moisture within the stone and cause it to weaken and deteriorate beneath and adjacent to the sealant. The sealant is disfiguring as well, and periodic replacement requires mechanical removal with a chisel or grinder, which can cause further damage. Not infrequently, glazing systems are mounted against masonry with mild steel or electrogalvanized fasteners which are susceptible to rust. Rusting fasteners can stain, or worse, spall the stone or brick.

Light Transmission and Protective Glazing

All secondary glazing, whether glass or plastic, reduces the light to the stained glass in some degree. For most types of glass and <u>new</u> plastics that are not hazed or yellowed, the light reduction is relatively insignificant. Clear/clean ¼" polished float glass reduces light transmission only 3%, while clear/clean ¼" *Lexan*® reduces transmission about 16%. Admittedly, the amount of daylight varies constantly for all stained glass depending on the time of day, cloud cover, shading from trees and buildings, etc; however, when dirt builds up on the inside surface of the PG, and when plastics are yellow and haze over time, the effect can be dramatic. These conditions not only reduce the amount of light, they change the color of light passing through the stained glass. **Inspired Partnerships** measured the change in light levels for the case study windows and found that the light level <u>always</u> went up; increasing from as little as 17% up to 103%! For examples, see case studies in **Section VI**.

Sound Transmission and Protective Glazing

All secondary glazing, whether plastic or glass, reduces sound transmission through the stained glass to some degree. This can be very beneficial under certain circumstances where excessive street traffic, airport or industrial noise negatively effects the worship service. Sound transmission qualities vary considerably between different PG materials and frequency of sound involved. Monolithic (single layer) plastics generally reduce sound transmission better than standard glass. Laminated glass, particularly laminated insulating glass however, is superior to monolithic glass or plastics in reducing sound transmission. When tested, these materials receive a "sound transmission class" (STC) rating depending upon their sound transmission loss over 16 frequency bands. For instance: ¼" float glass has an STC rating of 27; ¼" *Lexan®* has an STC of 31; ¼" laminated has an STC of 39 (depending on the interlayer); and ¼" laminated insulating glass has an STC of 48 (depending on the interlayer).

In practical applications, the true sound reduction value also varies depending upon the depth of the air space between the PG and the stained glass. The deeper the interspace, the greater the sound reduction (although there are negative drawbacks in trying to vent a deep interspace, see **Section VI.**). **Inspired Partnerships** measured the sound transmission of (generally) low frequency street traffic through the stained glass before and after PG was removed from the ten case study windows. Depending on the location of the church from the street, the amount of traffic, and the PG installation, sound levels ranged between 50 to 100 decibels. Under normal circumstances, the change in sound transmission with or without PG, was negligible (less than 3%). The highest sound transmission increase measured when the PG was removed was recorded at Covenant United Methodist Church (Evanston, IL) which had a 5½" interspace. Here, the average sound level increased from 87 decibels to 95 decibels (14%). Triple glazed units were not available for testing but would probably reduce sound transmission significantly and could be very effective under abnormal conditions.

Installation Guidelines for Protective Glazing

The owner should obtain a complete condition report of the windows to be covered prior to installing protective glazing. It is important to recognize that PG does not fix deteriorated stained glass, it only covers it up. There are instances where recurrent vandalism, stained glass conditions, or stained glass value warrants a "protective" glazing system. Conservation of the stained glass itself should of course be the overriding consideration for any installation. "Isothermal" protective glazing which remounts the stained glass on the inside of insulated glass, and vents the space between the two glazing systems, may be the best method in many instances for conservation of the stained glass. Even isothermal glazing with insulated glass cannot guarantee that condensation will never occur in certain circumstances. However, it will guarantee that no condensation will occur on the interior surface of the stained glass. This is a primary concern only in cases of unstable paint conditions with the historic glass. An isothermal system also allows for the rapid evaporation of any condensate that may form, usually protecting the window frame and surround from deterioration. Isothermal systems can also have an unacceptable architectural impact, and require careful design.

When designing the installation details of a protective glazing system, the following issues must be considered: the existing condition of the window and its surround; the effect on the aesthetics of the window and the building; the appropriate materials to use; the venting of the interspace; and the ease with which the system can be maintained. The following factors should also be considered in the installation of any protective glazing.

1. **Framework Configuration:** Successful PG installations mimic the shape of the tracery or mullions that support the stained glass. Installation of a grid or a series of horizontal muntins will almost always have an unacceptable architectural impact. If a window is placed high in a wall or clerestory, muntin placement should consider the viewing angle to avoid shadows on the glass when the window is viewed from the interior.

2. **Texture, Leading & Framework Color:** In buildings where the glass texture and leading pattern are important to the perception of the building, large sheets of PG are an unacceptable compromise. Similarly, windows with opalescent glass or other glass which has a distinctive appearance in reflected light may not be appropriate candidates for PG.

3. **Depth of Window Opening:** Installations which maintain a reasonable setback from the plane of the adjacent wall surfaces are generally more successful than those which do not. It is generally more successful to have the window moldings engage the PG, rather than to set it against them. Assuming that proper provisions can be made for expansion/contraction, installations which are set within existing tracery are more successful than those which "piggy back" new supports on top of the existing window.

4. **Glazing Attachment Method:** The attachment of PG is extremely important, especially when plastics are used. PG should never be attached directly to the existing frame, even where a bead of sealant seals it in place. The PG should be attached within the frame surrounding the stained glass and be securely anchored. It should not just hang on the existing frame of the stained glass. Thermal expansion of plastic glazing, especially with large glazing panels, will break sealant joints and leak. Glazing should be placed within sashes or reglets to allow expansion/contraction. All fasteners should be nonferrous.

5. **Frame Material:** In general, frame components should be fabricated of the same material (either metal or wood) as the original window surround. Metal muntins are rarely acceptable on a wood window. Bronze or anodized aluminum are acceptable, but mild steel will rust should not be used. In strong salt conditions (near coastal areas) special coatings or alloys may have to be specified so that the aluminum does not corrode.

6. **Glazing Material:** Tempered and laminated glass are durable, resistant to breakage, and do not have the expansion or discoloration problems that plastic sheeting does. Glass products are heavier, but are not more expensive to install than plastics when either material is installed properly. For the most part, plastics are more resistant to impact than all of the glass options. Plastic can be cut into complex shapes without risking its integrity. There are numerous tradeoffs for this increased strength. Plastics tend to bow

and distort however, especially in large sheets. While the degree to which they are effected varies depending on individual composition, all plastics are subject to scratching. In the advanced stage, the plastic becomes cloudy, restricting light transmission. The two most common generic types used are acrylics and polycarbonates. Both types have relatively high coefficients of expansion that must be accounted for during installation. The plastics field is one of constant research, developing new products all the time. New improvements are expected, however, any claim that manufacturers are not willing to put in writing should be ignored. Specific considerations for materials are as follows:

Plate or Float Glass. Large sheets of standard plate glass offer the most economical glass solution, but have the least impact resistance (with the exception of leaded PG).

Leaded Glass: If glass is cut and leaded together to form an exterior protective glazing, it is often the most aesthetically successful type of PG system. Dramatic impact resistance can also be gained by tempering the glass before leading. This method is very popular in European Cathedrals, for whom it was developed. The disadvantage of this approach is its cost which can range well over $100 per square foot.

Tempered Glass. Glass can be tempered by heat or hardened by a chemical process. The result is that the glass becomes up to ten times more resistant to impact than annealed glass (the transparent barriers on professional hockey rinks are tempered glass). Tempered glass maintains all of the glass attributes discussed in **Section III**. The greatest disadvantage is that tempered glass cannot be cut once its tempered. Therefore, the glass must be measured accurately, often necessitating templates (since windows are rarely perfectly square), which translates into a greater expense and attention to design. In addition, tempered glass (material only) cost approximately 70% more than plate glass, which increases total installation costs almost 20%.

Laminated Glass. This glass is composed of two sheets of annealed glass (or a layer of tempered glass) that have been laminated with a polyvinyl butyral interlayer. While the individual glass sheets are still subject to breakage, the strong interlayer will prevent most projectiles from passing through thereby protecting the stained glass. It is tricky to cut laminated glass in the field, but it is possible. Custom shapes can be fabricated in the shop, and they are only as limited to the skill of the cutter. Certain interlayers, such as Monsanto's Safeflex, will block 99.9% of the ultra-violet light, while maintaining total clarity. This is important if the use of epoxies has been specified in the restoration of the stained glass. Laminated glass (material only) is approximately twice as costly as standard plate glass which increases installation costs around 35%.

Acrylics (*Plexiglas®*): Acrylics have a harder surface than polycarbonates, and tend to be less flexible but are more resistant to scratching. They are effected by sunlight however, tending to yellow and become brittle with age.

Polycarbonates (*Lexan®*): Polycarbonates are softer than acrylics, and thereby more subject to scratching. They are also more flexible, which contributes to their greater resistance to

impact. If used in the correct thickness and installed correctly, polycarbonates are virtually unbreakable. The owner should inform the local fire department whenever polycarbonates are installed on windows; it is very difficult to break through polycarbonates in order to vent a fire. If polycarbonate glazing is not installed in the proper frame or appropriate thickness of material, serious repercussions may result. Framing that does not allow for its high coefficient of expansion may result in damage to the window surround. The appropriate thickness in relation to the maximum span must also be considered, or the polycarbonate can actually flex into the stained glass causing damage.

7. **Venting Protective Glazing:** The interspace formed by protective glazing must always be vented. There are three primary reasons for venting: to allow any condensate to evaporate and leave the interspace; to equalize the pressure in the interspace with that of the local atmosphere; and to minimize the temperature gradient for the leaded glass. Where and how the glazing is vented depends on the type of installation and the local environment. In a northern temperate climate, such as found in much of Europe and the United States, the interspace should generally be vented to the exterior of the building. This theory has been supported by testing in many European countries. In hot, humid sections of the United States, venting to the interior should be considered if the building is air-conditioned throughout most of the year. The venting needs of particular windows may vary greatly. The amount of venting required is dependent on the micro-environment that the window is subject to based on climate, orientation, and the depth of the interspace. Venting can be accomplished as follows:

Frames: If applied frames are used to support the PG, holes can be drilled through the members of the frame to allow air movement. The holes must be at the top and bottom of the window, placed in such a way as to discourage the infiltration of rain water.

Plastic: If plastic glazing is used, holes can be drilled through the plastic. Place them at the top and bottom of the lancet, and angle them up to prevent rain from coming in.

Glass: If the exterior glazing is leaded, vent panels (stainless steel screens) can be glazed into the window during fabrication. if laminated glass is used, the corners can be cut off (or the top three inches of a Gothic Head) and a hooded vent screen comprised of glass, stainless steel screening and lead came, can be fitted to the system.

It is better to <u>not</u> apply protective glazing, than to apply it improperly. The most common result of improper installation is condensation. Moisture gets trapped between the glazing and condenses on the stained glass, framing members, and the surrounding window. The moisture promotes corrosion of the glass and the metals, rots the wood, and may contribute to spalling of the masonry. Even the lead came of the window may be attacked by organic acids produced my micro-organisms that live in the condensed water. Unvented interspaces can also be subject to extreme temperatures as solar radiation is absorbed throughout the day. The absorbed heat is transferred directly to the window, augmenting the deleterious effects of the expansion and contraction cycle (see **Section VI.**)